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Chapter 8
Intelligent Decision-Support in Virtual Reality Healthcare and Rehabilitation

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Abstract. Intelligent Decision-Support (IDS) mechanisms to improve an 'in-action' facilitator intervention model and 'on-action' evaluation and refinement model are proposed for contemporary Virtual Reality Healthcare & Rehabilitation training. The 'Zone of Optimized Motivation' (ZOOM) model and the 'Hermeneutic Action Research Recursive Reflection' model have emerged from a body of virtual reality research called SoundScapes. The work targets all ages and all abilities through gesture-control of responsive multimedia within Virtual Interactive Space (VIS). VIS is an interactive information environment at the core of an open-ended custom system where unencumbered residual function manipulates selected audiovisual and robotic feedback that results in afferent-efferent neural feedback loop closure. Such loop closure is hypothesized as the reason why such interactive system environments are so effective in the context of rehabilitation and healthcare. The approach is adaptive across the range of dysfunction, from the most profoundly disabled to traditionally developed. This proposal considers enhancing VIS data exchange, i.e. human input information matched to responsive content, through dynamic decision-support of adjustment of difficulty encountered. To date facilitator role has included manual parameter manipulation of interface to affect an invisible active zone quality (typically, sensitivity or location) and/or content quality. In-action human adjustment-decisions are according to interpretation of user state and engagement. Questioned is whether automated support for such decisions is feasible so that dynamic difficulty adjustment (DDA) of that which is encountered by the user is considered optimal to goal. Core issues are presented to detail and justify the concept. Findings are related to current trends with conclusions reflecting on potential impact.

Keywords: Afferent-Efferent Neural Feedback Loop Closure, Gesture-control, Sensor-based Interactivity, Virtual Reality Healthcare & Rehabilitation, Virtual Interactive Space (VIS), Dynamic Difficulty Adjustment (DDA).

1 Introduction

This position chapter discusses a body of research that originated from a teenager's simple interactions with a profoundly disabled uncle. Empowerment

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was through adaptive use of a traditional foot pedal device normally used by a guitarist to control musical parameters. Manipulation of auditory feedback was via upper torso gesture that raised or lowered the pedal positioned under an elbow. Euphoric response and continued, motivated interactions followed with resulting life quality change and well-being alongside improved communications and social interactions by the disabled uncle.

The profound impact and understanding of potentials from empowering leisure, recreation and entertainment as fun training through sensing technologies and responsive multimedia were not realized until a decade and a half later. A hybrid electro-acoustic instrument to empower disabled people to be able to creatively express and freely play with sounds through residual gesture was realized. Subsequent studies explored beyond solely auditory. Motion controlled audiovisuals and robotic devices was also explored as feedback stimulus.

To date, abductively-generated models have evolved from SoundScapes' applied research. These models focus on how (1) facilitator intervention optimizes motivated-participation in technology-enhanced therapeutic training sessions, and (2) how original session material is analyzed and reanalyzed recursively to optimize knowledge and knowing. Each model is presented in this position chapter.

Sessions using this form of 'training' differ from traditional rehabilitation intervention as fun user-experiences are targeted via gesture-control of virtual reality (games or abstract content in the form of digital painting or music making). Thus, a whole person-approach rather than a traditional therapist approach to intervention underpins the work – this is described elsewhere in this chapter.

A hypothesis is that intelligent decision-support in the form of machine-learning can be developed to improve such intervention that has a goal of life quality. This position hypothesis is posited in this chapter.

The next section outlines the original apparatus and method that evolved from the research to be responsible for a patent [10] on how gesture-responsive non-intrusive sensor-based interactive multimedia can be used in non-formal healthcare rehabilitation, and education. A background section then follows which informs how performance art has been influential in development of the concept.

1.1 Outline

A prototype open-ended interactive multimedia system was created to investigate a discovered need of how people with profound disability, who for example cannot hold a traditional musical instrument, paint brush or computer mouse, desire to express themselves creatively and playfully just as others of higher function are able to.

To enable access to such expressivity, the system utilizes whatever residual physical function is available to generate data via movement within active sensor spaces. Generated data controls multimedia.

This player space is central to the interactive virtual environment referred to as Virtual Interactive Space (VIS)[7].

The invisible space that acts as the human interface to the open-ended system is flexible in that it can be volumetric/3D, linear, or planar according to technology used (figure 1). The technologies can also be mixed and matched to suit each case.

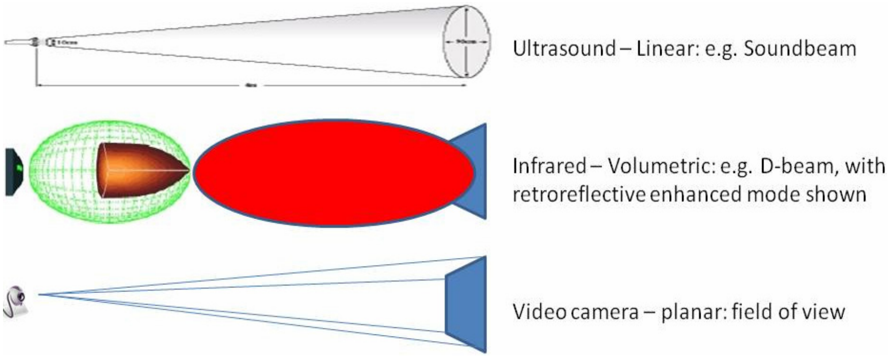

Fig. 1. Non-invasive sensor profiles used in SoundScapes

The sensors are non-invasive to enable data-generation from unencumbered motion, i.e. no need to wear, hold or touch any input device. The unencumbered gesture controls responsive multimedia that is pleasing, direct and immediate so as to digitally mirror input to stimulate the user to further react intuitively in such a way as to become immersed in the interaction. Motivation is augmented. The mirroring technique reinforces a participant's awareness of movement and proprioception and is developed from observations of traditional silver mirror use at rehabilitation institutes to train profoundly disabled.

Aesthetic Resonance (AR) [11] is targeted as exhibited user state via the mirroring technique. This is achieved from an optimized session set-up and experienced facilitator intervention. In such a set-up, mediating technology affordances influence a user's sense of self-agency leading to empowerment and potential microdevelopment. The aesthetic value relates to how the user recognizes associations between input physical action/motion and the abstract feedback that stimulates further action. Resonance is a known quality of the motor system in how it responds during observation of an action [47]. This form of resonance behavior links directly to the human condition, and the body's capacity for 'release phenomena' [57] and 'response facilitation' [12]. Related resonance is where higher order motor action plans are coded so that an internal copying of the observed action - in this case the multimedia response; is not repeated but is rather used as the basis for a next action [47]. In this way Aesthetic Resonance associates directly to closure of the afferent-efferent neural feedback loop, which is suggested as a reason why interactive multimedia is so effective within rehabilitation training [11].

The next section introduces the background of the work.

1.2 Background

The patent [10] resulted from the author's research which began around 1985. The concepts and approaches in SoundScapes evolved from an engineering education, artistic background (e.g., early work shown at The Institute of Contemporary Arts

(ICA), London around 1975), and close association with severely disabled family members.

Over the years, SoundScapes has been used in the author's own stage productions and performances, interactive installations (e.g., in Museums of Modern Art, international commissions), and as a therapeutic supplement in healthcare and rehabilitation. It is the latter that is in focus of this chapter, however linkages to performance art should be evident to those in the field.

The research explores alternative means of creative expression and focuses on invisible collection of body function signal data.

Since the research beginnings, systems to explore the concept have been created with a variety of mediums, i.e., arrays of input motion sensing devices mapped to an assortment of (output) multimodal contents. These have led to the current open conglomeration where hardware and software are mixed and matched appropriate to the user.

User groups

Attention for the therapeutic work has been to users who are profoundly disabled. This is a community consisting of many who are unable to speak, yet, through their idiosyncratic means, are able to communicate to guide facilitator intervention. Intervention in this case refers to the actions taken by the facilitator in training sessions.

Much has been learnt from such sessions with extreme cases where the author has had the role as facilitator and designer working with therapists and healthcare workers that usually know the user well. Such learning has contributed to the system, conception and methodology resulting in it being successfully applied within other sectors of disability with people having higher functions. These include acquired brain injury (stroke), Down syndrome, Cerebral Palsy, and many others. Increased use is also in the growing sector of aged towards supplementing future service needs.

Recent adoptions by healthcare and rehabilitation professionals of affordable commercially available game systems, such as Nintendo Wii, correlate to the author's original concept. Such contemporary game platforms utilizing alternative sensor-based gesture-controllers improve upon the author's basic gesture-controlled interactive non-abstract content, i.e. video games. These have been used in SoundScapes' therapeutic situations since around 1998.

An example of game-based intervention is where the Sony EyeToy was used in a study designed and led by the author involving children (n=18) at two hospitals in Denmark and Sweden. The children, 10 females and 8 males, were of high function and across the age range of 5-12 years-of-age, (mean 7.66). Control was those not in sessions.

The children's gesture controlled screen artifacts which motivated further interaction and physical activity [9]. Doctors and play therapists who conducted the clinic sessions responded favorably to children's reactions. However, in this investigation the design was that there was no opportunity given for the facilitator(s) to change game parameters. Thus, those with high competence quickly became bored. Equating to the state of flow [15, 16, and 17] being diminished. A need was for parameter programming change of both human motion data capture device (i.e. feedforward) and presented content, i.e. visuals, audio, (i.e. feedback). Addressing this need in a high-quality game is unusual, yet, it would give opportunities for facilitators to adapt the situation to maintain user engagement and motivation.

Differing from this example is a SoundScapes study with learning challenged individuals at a school for cultural education and at a special school for youngsters who are profoundly disabled [8].

The open-ended system enabled programming of both feedforward and feedback that enabled facilitator parameter change to motivate the users in an optimal way. This is often done on the fly in response to user interaction with the mediating technology.

Reflecting this need for an open-ended system and approach this chapter presents the models that support the decisions in sessions as well as suggesting the related next step to further the work through machine-supported decision-making to support the service personnel load of the future. Machine-supported decision-making is seen as a means to optimize calibration and adaptation of the interface in 'real-time' that is matched to the content control.

The next section briefly introduces the concept and open system conglomerations including the focused system that was created to be adaptive to individual needs and preferences. The facilitator role is presented in the subsequent section followed by a section on in-action and on-action decision-making.

2 Concept Need and System Conglomerations

Population demographics are changing dramatically so that aged and disabled are predicted to increase at an astounding rate. The concept in question was designed to be open and without constraint of user ability or age. It has been subject of research and development since the mid-nineteen eighties and application is reported in numerous articles. It has evolved through experimentation and prototype iterations via system conglomerations consisting of libraries of input device and output content that can be mixed and matched and subsequently further tailored to be adaptive to a specific user and therapist goal. Custom setup designs include sensor-based input control devices that are worn (e.g., biofeedback), non-invasive (e.g., invisible such as cameras, infrared or ultrasound), or free-standing/or held (e.g., video game controllers). These devices offer various opportunities for alternative means of interaction of various interactive content such as abstract artistic expressions (e.g., painting or music making), robotic devices, or digital video games. More recently, affordable commercial systems such as Sony's Playstation EyeToy®, GestureTek's Interactive Virtual Reality Exercise System (IREX®™) and Nintendo's Wii®™, and others are also used.

The author's created conglomerate system that is in focus in this chapter suggests advancement beyond such commercial game systems for use in healthcare and rehabilitation. The possibility of personalization, i.e. of both feedforward and feedback interaction is directly associated to the decision-making topic of this chapter as this is a need for future efficient systems to optimally motivate participation.

2.1 Adaptive to Individual Needs and Preferences

The concept involves system adaptation according to each user's needs and preferences. Programming flexibility of the created environment/situation (referred to as Virtual Interactive Space (VIS) [7]) enables sensitivity of sourcing human data (mostly motion) to be tailored to the individual and then mapped to responsive medium(s). This is presented in such a way to stimulate the user to react according to a therapeutic training goal. As presented earlier in the chapter, user *afferent-efferent neural feedback loop closure* is suggested achieved in this way (figure 2).

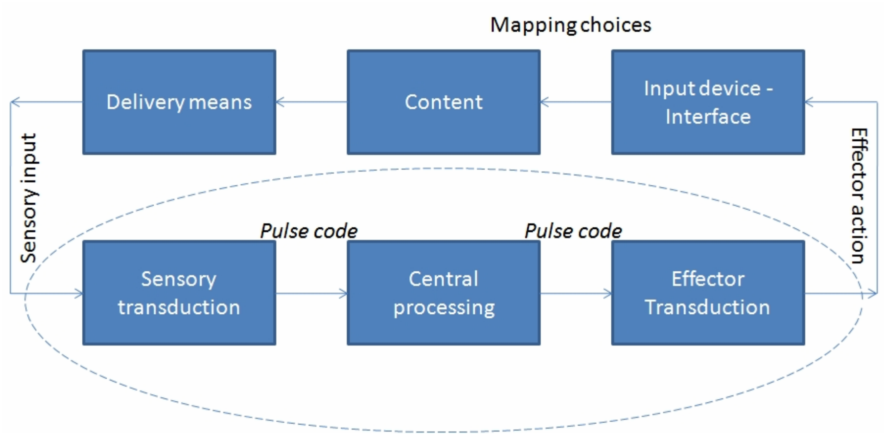

Fig. 2. Afferent-efferent neural feedback loop closure [see also 11]

In figure 2 the dotted oval represents the human and the objects are the data signal processing (DSP). Effectors action is captured by the sensing device and sensory input is presented via display (visuals) or speakers (auditory). Re-programming (configuration change) of the VIS input device and content is according to user reaction and is carried out by the facilitator in the action phase of the session. It is also reflected upon post-session and the system is refined accordingly. By affecting incremental VIS changes, *reafferentation* training is evoked (figure 3). This is a strategy of change where a familiar goal e.g. a sound according to a specific location in space is changed to induce user detection of error, search to correct, and subsequent correction and re-learning of new location. This technique is used to extend movement without engaging at a conscious level. Decisions innate to SoundScapes are evident of facilitator reafferentation strategies for each user and this is optimized through the use of invisible interface technologies [e. g., 7-11]. In other words, this form of training is where familiarity of the location of action effect (i.e. revisited causal - data/feedback -hotspot) is manipulated through facilitator change of system parameter (e.g., head direction/location, sensitivity of sensor). Locations of no-action 'stillness' zones are also designed for PMLD participant communicated "pause", "change", or "end"…etc.

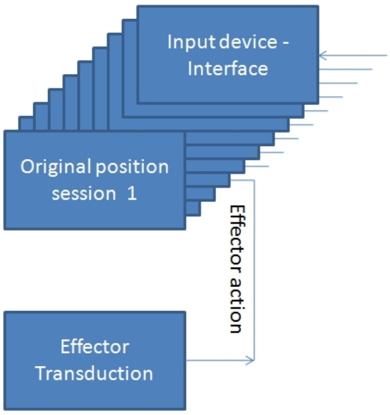

Fig. 3. Reafferentation training: incremental movement change of feedback stimuli

2.2 Facilitator Role: Intervention

A main role of the facilitator in this applied research is to support the user's perception of what can be done. Empowerment of 'doing' is essential for user-experience. As stated previously, in most instances an input device that is based upon technology that is invisible to the human eye is used (e.g., infrared, ultra-sound, or camera – figure 1). In these cases the feedback content acts as the direct communicator of feed-forward action and thus becomes the 'perceived interface'. This direct and immediate causal feedback loop, if optimally configured to be interesting and engaging, motivates user participation. However, such engaged motivation can become problematic as user-drift from the interface sensing area can occur, e.g. via over-enthusiasm.

The facilitator must ensure positioning of the means to source the human gesture is optimal (input device location, direction, and setup) along with appropriate content with affordances to guide the user to remain connected to the sensing input device so that perceived 'doing' (i.e. interaction with the multimedia) is intuitive. This also assists motor control training and associated cognitive relations to same. Goal-directed user behavior is targeted via facilitator system-change decisions based upon expert input (therapist, professional healthcare, and/or family/friends) such that user sense of self-agency is achieved that leads to a user sense of empowerment. This inner empowerment is represented externally through non-verbal indicators such as facial responses, eye contact, and interactions. The feedback-feedforward link is thus responsible for ensuring action possibilities available in the environment are evoked as natural. However, even if the VIS is optimally set up as outlined so that the user is immersed in the experience it is meaningless unless the user can perceive what he/she can achieve through participation. This instructive, often demonstrative, facet of facilitator intervention is often overlooked as such instances involve improvisation that often involves physical guidance of the known user abilities alongside knowledge of both the input device (interface) and the mapped content. In-action decision-making is where a system-change is deemed required to maintain and optimize motivation of a user when undergoing a training session with the responsive virtual reality/multimedia system.

On-action decision-making reflects on archived video footage and other triangulated material from a session along with facilitator notes and recall. In-action decision-making is at the sole discretion of the facilitator conducting the session with the participant as these are usually one-to-one[1] with a target to promote self-driven play, i.e. without facilitator intervention. On-action decision-making can involve additional input such as therapist, healthcare professional or even family who can suggest preferences when the user has no verbal ability. The role of facilitator involves intuitive reflection and action in the form of system change based upon close observation of the user's exhibited reactions and emotions, i.e. feedforward, as well as the system response to user input, i.e. feedback. The facilitator role involves using one's own embedded 'enactive knowledge', which associates to tacit knowledge and is 'learned by doing'. It is based on experiences of perceptual responses to action, both from the feedforward (observed user) and feedback (observed system response) perspective. Facilitator action (ongoing decision-making activity) is thus a response to evaluation of user activity that is reactive to the system (and system-change, which is the decision made by the facilitator). In this way Varela's model of 'enactive cognition' [58] is associated. This type of evaluation has been suggested as 'the most direct, in the sense that it is natural and intuitive, since it is based on the experience and on the perceptual responses to motor acts' [25, p. 2].

Decision to change is developed through applying the system in various contexts and then subjecting the decisions and the reasons behind the decision-change to subsequent analysis. Complexities are inherent to such decisions that are based mostly upon subjective evaluation of exhibited user reactions to improvised (experience-guided) intervention. Experiences thus assist such complexities due to learning from making wrong decisions of change system parameters.

2.3 Motivation

Motivation is defined as a feeling of a need to do something [35] and it is this feeling and need that is a goal of design, intervention and refinement in respect of both participant and facilitator in SoundScapes. Included in system use exploration is a dynamic relationship between the inter-related human attributes of 'emotion', 'motivation', and 'movement' (both adapted and non-adapted). Association is through the word emotion deriving from Latin *e movere*, meaning 'to move' or to produce movement. Relationship between emotionality and adapted/non-adapted movement is well-documented in the literature e.g. [35]. Optimization system use is through matching change parameters to an individual profile so that fun is had. Fun relates to joy, which can lead to development [30]. However, emotion, motivation, and movement are all dependent on effective and competent parameter change that does not interrupt participant or facilitator engagement in a session.

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[1] Usually the participant's care-person attends the sessions to ensure well-being.

Intrinsic motivation is where engaged participation in a personally challenging activity is just for the sake of participating. This stimulates interest, curiosity, satisfaction and enjoyment without thought of reward [56]. Intrinsic motivation links to the gameplay approach of SoundScapes intervention; it is linked to *autotelic* [55] and *flow* state [15, 16, and 17]. Intrinsic motivation is considered conducive to creative expression, whereas, extrinsic motivation, i.e. reward based, is considered detrimental [2, 3]. Both can be implemented in design/refinement of a SoundScapes session. When extrinsic motivation is required, for example, a created digital painting from gesture-control can be shown to others acting as a simple reward goal [8].

Experiences from sessions suggest that the motivation continuum between intrinsic and extrinsic can be improvised in the intervention phase according to participant profile and responses. However, when the feedback content is optimal and the participant is in flow state, more often than not, the facilitator role is passive. Participant departure from flow promotes increased activity by the facilitator to address participant motivation through parameter change or guidance and support.

Facilitator diligence of participant motivation signifiers is important. Such signifiers are important because they guide the facilitator in his/her intervention strategy.

SoundScapes intervention strategy has evolved through experiential analysis of sessions that have a goal of enriching a life. The strategy is informed through reflective analysis both in-action and on-action, especially of original video recordings, of own experiences, especially mistakes. The next section closes the evaluation section by presenting the model for intervention that has abductively evolved.

2.4 Intervention Model for Decision-Making

A session facilitator is acknowledged as having a key role in intervention with disabled individuals, e.g. [23, pp. 72-74] [40, pp. 49-50]. Improvised intervention, passive or active, is via available system tools (system change parameters made available by session design/refinement). Optimizing participant 'mirroring' is via these resources. Implementing these resources is the foundation of the concept of 'Zone of Optimized Motivation' (ZOOM) (Figure 4).

ZOOM reflects facilitator intervention specific to system use where motivation is optimized (shaded diagonal) and flow state present. It is considered needed to contextualize how knowing the right time for introducing change (δ) can lead to further development [14]. Participant competence over challenge for a period of time can start to wane motivation as familiarity or boredom emerge, recognizing this, the facilitator can change a system parameter so that a new challenge provokes augmented participant input. Changes are participant dependent and flexible along a motivational continuum. In other words, they can be organized around tasks - motivationally extrinsic and discrete, i.e. in steps, or configured to be more intrinsic to motivation perceived as continuous, aimless and exploratory where, seemingly, tasks are self-determined [27]. Incrementing challenge can also provoke motivation/learning collapse in line with Yan and Fischer [62]. When a collapse is recognized, often signified by participant disengagement followed by

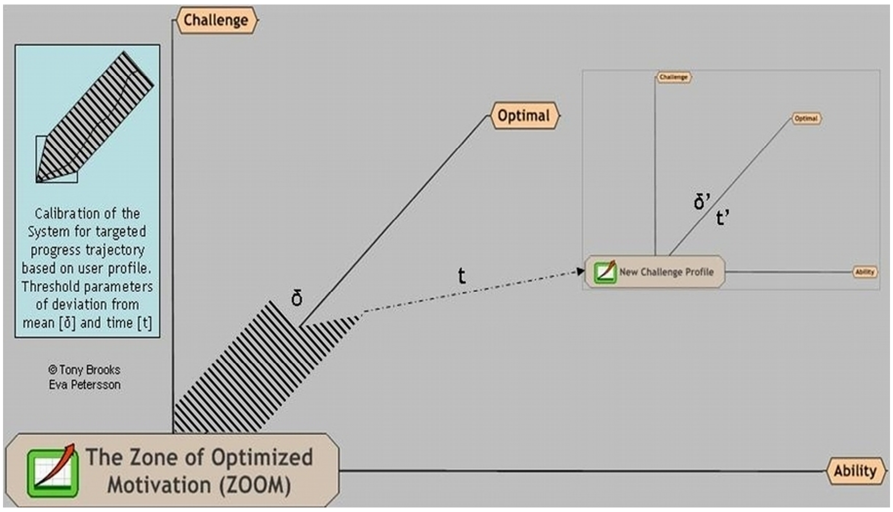

Fig. 4. The Zone of Optimized Motivation (ZOOM)

communicative gesture, the facilitator has to decide on the intervention step of either allowing time (t) for new 'learning' to evolve, or alternatively, to return to a prior challenge level, or even to a preceding (easier) level to again motivate participation. Facilitator experience and knowledge of participant profile guides such decisions. Attending caregiver assists by close observation with the aim of preventing participant over exertion and ensuring well-being.

An experienced participant can also communicate when a change is required, either within the current genre (e.g., sound patch change) or more diverse across modalities (e.g., from music to painting or game). Such a communication is where the participant uses what is referred to as the stillness zone, or non-active area. Such use is an indication of learning in profoundly disabled individuals. The process of facilitating is improvised, iterative and not as clear-cut as may be believed due to participant idiosyncratic traits. Many need initial guidance [49, 50] (physical or imitation) to articulate, especially the inexperienced. Such scaffolding [61] is inherent in the facilitator intervention role.

3 Therapeutic Applications

Rizzolatti and Arbib [48] inform how the human performance system has the capability to observe and recognize motor actions of another individual through neural representations that use the resultant information to map and execute similar actions as imitation. Motor neuron behavior is thus reactive to meaningful visual input. They further inform that the motor system 'resonates' during the observation and they link resonance behavior to *release phenomena, learning and instinct* [57] as well as to 'response facilitation' and cognitive processing [12].

These issues are discussed elsewhere in SoundScapes research and for the sake of brevity are not expanded herein.

In SoundScapes, rather than considering observation and recognition of another individual, a belief is that brain-generated actions are stimulated from recognition (not necessarily consciously recognized) of associations between self-generated feedbacks to feedforward actions that are self-emitted (consciously intended or a subconsciously responsive action to stimulus i.e. not consciously reacted upon but stimulus-driven). Feedback is primary, i.e. self-recognition of feedforward motion, and secondary via the mediating content stimuli that results from the motion. As both feedforward excitation and feedback association are adaptive a form of digital mirroring ensues. This induces closure of the afferent-efferent neural feedback loop [11]. The adaptation of the system-change parameters by the facilitator addresses intention, instinct and reaction interpreted of user input action and reaction. The reaction informs of user motivation, interest and engagement and it is these cumulated representations that act as guide to facilitator improvised control of the system.

A metaphor to this facilitator role is of a puppeteer who manipulates the strings to control interactions, in this case the available system parameters are as the puppeteer strings and the puppet is the user. However, the metaphor is temporary as the user reacts to perceived system affordances and develops recognition of causal competence that result in sense of self-agency, which leads to inner-empowerment that becomes externally represented. A form of micro-development ensues that relates to learning according to system design and therapist goal. However, system-change parameters are under the control of the facilitator and often mistakes are made of when to change and to what extent the increment of change should be. Over the years this has been a learnt process that is ongoing. Reflective of this acknowledgement is the emergent model titled Zone of Optimized Motivation (ZOOM).

3.1 Evaluation

Evaluating system use includes assessing participant response, and this is acknowledged as complex [33]. In line with [37, 38] qualitative inductive research methodologies were researched and selected to be integrated with the goal to create a flexible, multidimensional model to critically understand what was involved in system use. Background and development of the emergent model for intervention and evaluation is presented in the following sections.

SoundScapes has been evaluated to enhance social interactions, competence development, and cognitive/physical improvements [7, 39]. Participant awareness of enhancement, along with fun from interactions, both with system and facilitator, contribute to motivation. Change is targeted through intervention and is acknowledged in Action Research methodology. The next section introduces Action Research as an element of the method foundation.

3.2 Action Research

Figure 5 illustrates two sequential iterations of an Action Research process. Kemmis & McTaggart [31] describe Action Research as a “spiral of self-reflective cycles of planning a change, acting and observing the process and consequences of the change, reflecting on these processes and consequences, and then re-planning, acting and observing, reflecting, and so on…" (p. 595). In SoundScapes it is considered a social model e.g., due to how planning considers influence of attendees, that fits well with the activity theory framework described earlier. In this research it contributes as a sequential 'interactive inquiry process' [44]. Environments are both the physical situations where sessions take place and the virtual environments that are encountered in the session. Facilitator attention is acknowledged as influential in case studies conducted under an action research methodology that involves action and learning [36]. Curry [18] informs how "action research requires trust, openness, high tolerance for uncertainty and surprise" (p. 6). These have been found as key aspects in this specific intervention with disabled people.

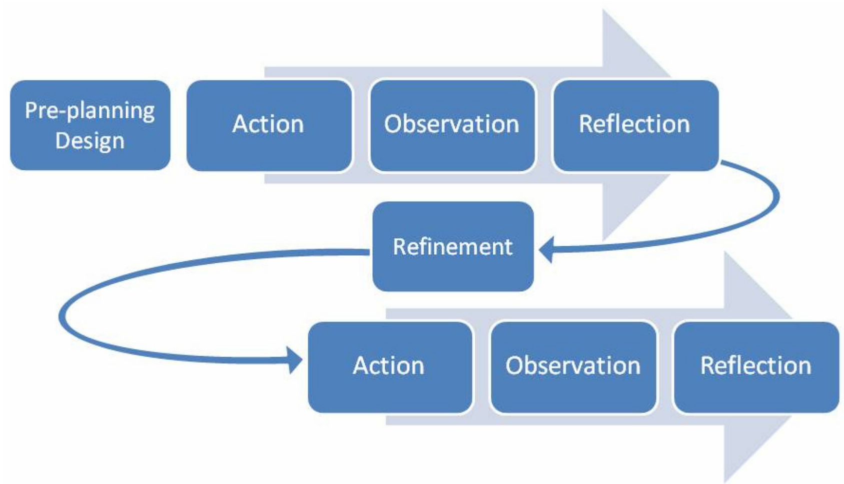

Fig. 5. Example of two iterations of Action Research process

To satisfy the investigation the temporal linear/sequential profile of Action Research required enriching thus a synthesis with a second approach having an opposing non-linear recursive profile was made. Mahoney [35] relates how motivation theorists suggest hypothetical tensions resulting in polarized concepts or operations promote activity and learning. The multidimensional profile that has evolved is illustrated in figures 6(a-p) on pages 156-161. Evaluation was recursive considering both linear and non-linear dimensions of archived triangulated material, which assisted both in-action and on-action reflective analysis [53, 54]. Hermeneutic enquiry was found fitting to complement Action Research, especially as the approach could be interpreted to investigate systemically between part and whole to explore dynamic relationships [21].

3.3 Hermeneutic Spiral

Hermeneutics is a flexible core interpretive tool suitable for retrospective reflection of whole and part [28, p. 134], and is acknowledged as an iterative strategy creating knowledge and knowing [1]. The focus is upon the relationship between the whole and the parts, which are dependent on each other, and together they create understanding. The approach was considered complementary to Action Research and the iterative research and development profile of SoundScapes. Schleirmacher [52] had an emphasis on knowledge creation through the hermeneutic circle as a dialectic movement between part and whole with an emphasis on understanding in relation to modes of communication. In other words, understanding of the whole by reference to the individual parts and understanding each individual part by reference to the whole. His focus was on how the interpreter was important in the process of interpretation and for successful interpretation prior understanding was involved. [26] also emphasized that a necessity was pre-understanding within the process of understanding and accordingly extended the hermeneutic circle as a spiral; thus with a temporal form. The act of interpretation, i.e. the giving of meaning to something, has a time dimension and thus, in SoundScapes, interpretation of data is via forward sequential Action Research complemented by the retrospectively non-linear hermeneutic approach. Interpretation is of activity, user-experience, and learning.

The importance placed on reflection of how experiences between an individual and an environment can support development is not new [5, 32]. The synthesis of method (action research) and approach (hermeneutics) conducted as 'recursive reflection' is in line with Eden and Huxham [22, p. 81] who state how it is crucial that an appropriate degree of reflection is built into process, and that the process includes a means of holding on to that reflection. Further, Brooker et al. [6] attempted enriching outcomes of action research through a Hermeneutic spiral in a different context.

3.4 Hermeneutic Action Research Recursive Reflection

Resulting inductively from explorative enquiry to influence and support decision-making in virtual healthcare and rehabilitation is an emergent evaluation model titled 'Hermeneutic Action Research Recursive Reflection'. The term 'Recursive' is used fitting the iterative model of enquiry where all original material is available to be analyzed and continuously reanalyzed in light of new knowledge gain. 'Reflection' is used in reference to how experiences evolve into learning. The model involves the creation of an (all data) archive, i.e. a repository consisting of session notes, participant journals, video recordings, interviews, questionnaires, concept/mind maps, in other words all triangulated materials resulting from sessions. Subsequent evaluations and re-evaluations add to the archive. The process of Recursive Reflection is central to Hermeneutic Action Research as it signifies process of reflective analysis. The following figure sequence (denoted as figure 6a-p) illustrates how the Recursive Reflection model is flexible to address session-to-session analysis and refinement.

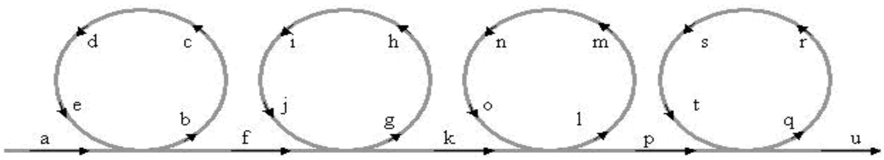

Fig. 6(a). Illustrates a typical four cycle/session action research profile. This consists of sequential segments:- (1) planning a change via action [segment a]; (2) action – the actual session with participant [segment a-to-b]; (3) post-session observation of the action [b-c]; (4) reflection on the action [c-d]; (5) refining – e.g. of the created system set-up or strategies to address the natural systems [d-e], and (6) the planning for the next action [e-f]… and so on for the other cycles.

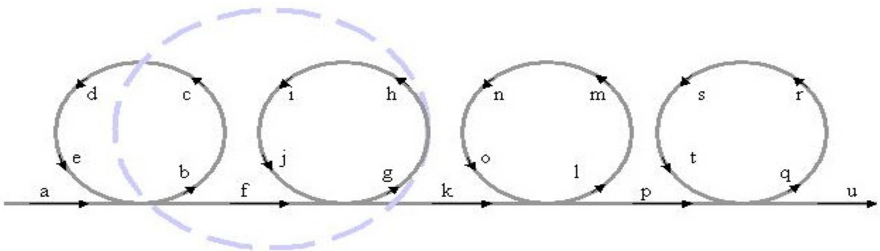

Fig. 6(b). This is the same four-cycle Action Research sequence plus a single retrospective hermeneutic on-action recursive reflection (shown as dotted line of anticlockwise direction). Initiated from a point in time during the observation segment [g-h] on action [f-g]; this indicates that prior session recall [a-e] was stimulated with most recent data acquisition [f-g] to prompt a researcher decision to initiate a secondary reflection on the initial session archive. In other words, what was learnt from experiencing action [f-g] stimulated a recursive reflection of preceding session action and observation. This process is illustrated in the figure by the start of the dotted line emitting upward and anticlockwise from the observation segment [g-h]. Retrospective reflection of the prior session includes the researcher consulting previous session notes, videos and other triangulated material. This reflection is 'on-action' segment [a-b]. The researcher then has additional material informing to the research as a whole, as well as to the second action cycle/session [f-j]. Findings augment observation segment [g-h] of session action [f-g], subsequently improving the reflections in segment [h-i], and ultimately influencing refinement in [i-j] and next iteration planning [j-k]...etc.

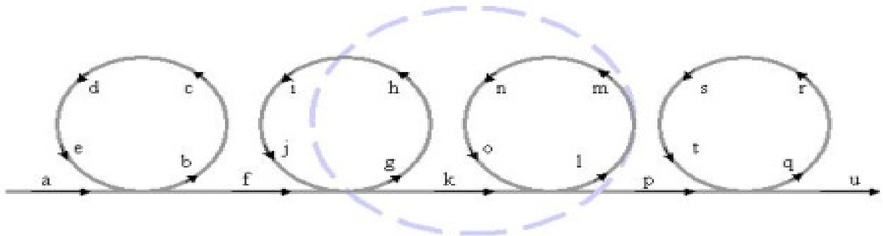

Fig 6(c). Four-cycle Action Research sequence integrated with a single hermeneutic 'on-action recursive reflection' (shown as dotted line of anticlockwise direction). This reflection initiates from a point in time located between [l-m] but instead originating from the third session observation segment as a reflection on the second session action segment [f-g].

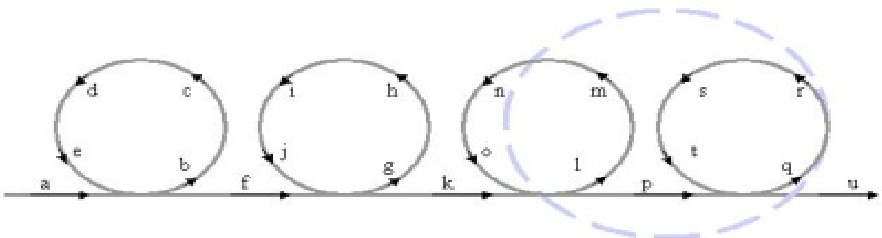

Fig. 6(d). Similar to above but initiated from the fourth session observation segment [q-r] in respect of 'on-action recursive reflection' of the third session action segment [k-l]

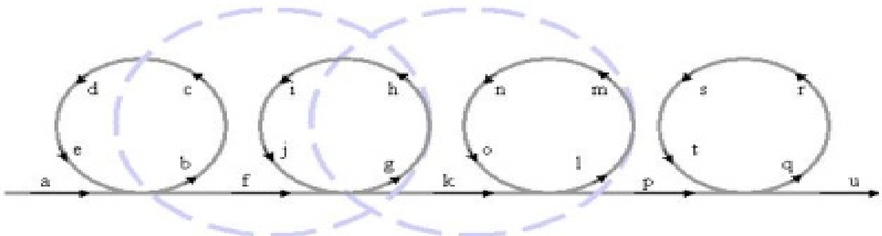

Fig. 6(e). Two iterations of the retrospective hermeneutic 'on-action recursive reflection' are shown where additional knowledge was believed available from the first session [a-e] based upon what had been observed in the second session [f-j]. Similarly, the second session offered additional learning for the third session.

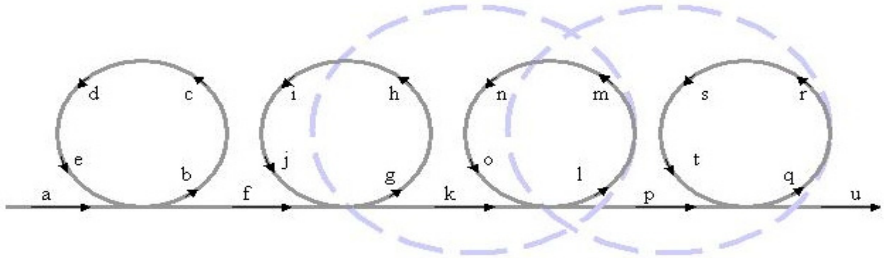

Fig. 6(f). Two iterations of the retrospective hermeneutic 'on-action recursive reflection' are shown originating from session 3 and session 4 observation segments respectively

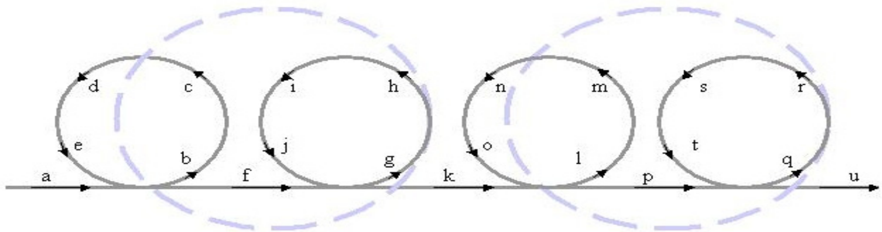

Fig. 6(g). Two iterations of the retrospective hermeneutic 'on-action recursive reflection' are shown originating from session 2 and session 4 observation segments respectively

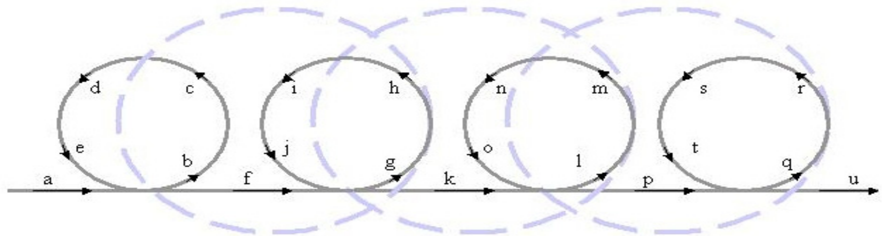

Fig. 6(h). Triple hermeneutic 'on-action recursive reflection' over a four session program where each subsequent session is systematically accesses prior session data

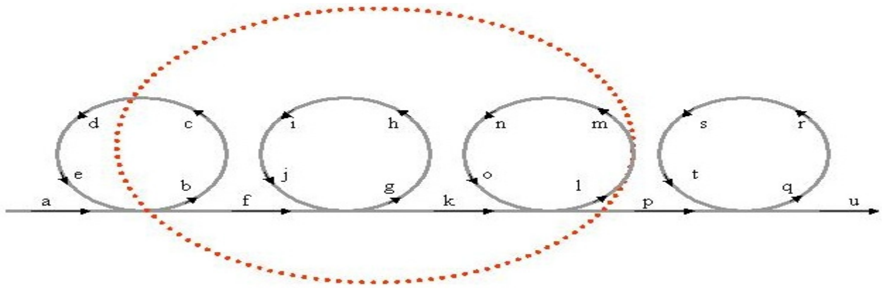

Fig. 6(i, j, k). Above and the next two images illustrate further examples of single and double retrospective hermeneutic 'on-action recursive reflection' applied upon an action research four session program. These illustrate that the model is not limited to retrospective sequential application as application is from any session in respect of any prior session.

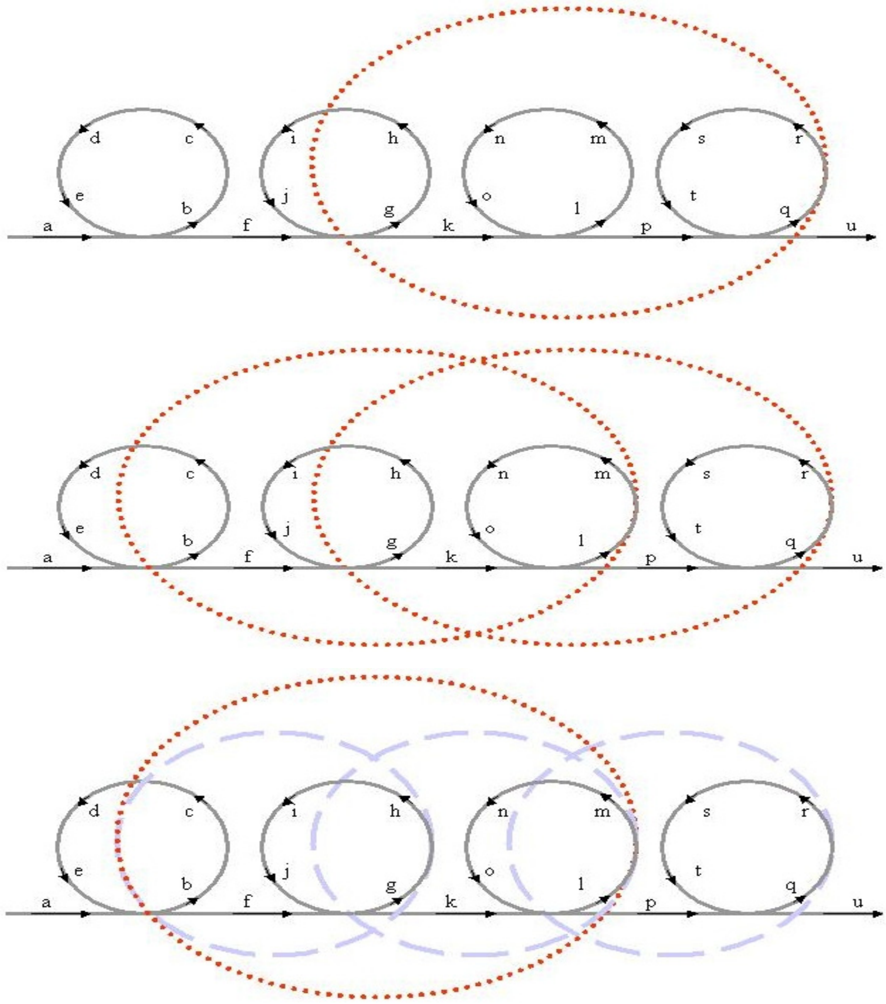

Fig. 6(l). Preceding figures illustrate retrospective 'single non-sequential' combined with a 'triple sequential' hermeneutic 'on-action recursive reflection' applied over a four-session action research sequence. The above figure interpretation reads as either:-

(1) Initial findings from the observation phase [l-m] of the third session action promoted an additional 'on-action recursive reflection' upon the first session, which was then brought into the observation segment of the third session, which in turn promoted an 'on-action recursive reflection' upon the second session action,

– [a-b-c-d-e-f-g-ω-h-i-j-k-l-ω-m-n-o-ω'-p-q-ω-r-s-t-u] …or

(2) Findings following the reflection and refinement on the third session promoted an additional 'on-action recursive reflection' upon the first session before a satisfactory planning for the fourth section was completed -

[a-b-c-d-e-f-g-ω-h-i-j-k-l-ω'-m-n-o-ω-p-q-ω-r-s-t-u]

…where omega [ω] represents a retrospective sequential hermeneutic ‘on-action recursive reflection’ and omega’ [ω’] represents a ‘single non-sequential’ hermeneutic ‘on-action recursive reflection’. Thus the model is flexible in that the hermeneutic ‘on-action recursive reflection’ can be following the session action of after a full review of the session.

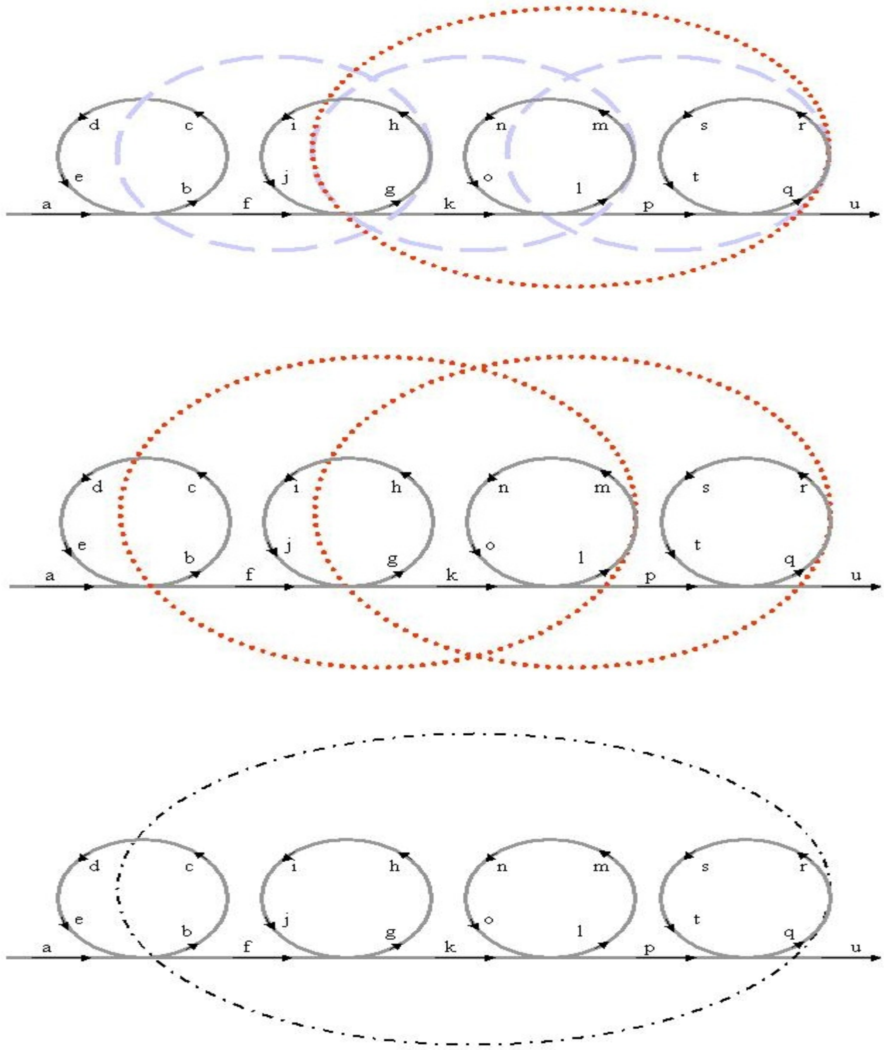

Fig. 6(m, n, o). These figures above illustrate examples of non-sequential’ hermeneutic ‘on-action recursive reflection’. An emergent model for systematic evaluation of subjective data has evolved out of an attempt to elicit maximum session data to inductively inform and evolve the research theories – see final (next) image with all options illustrated.

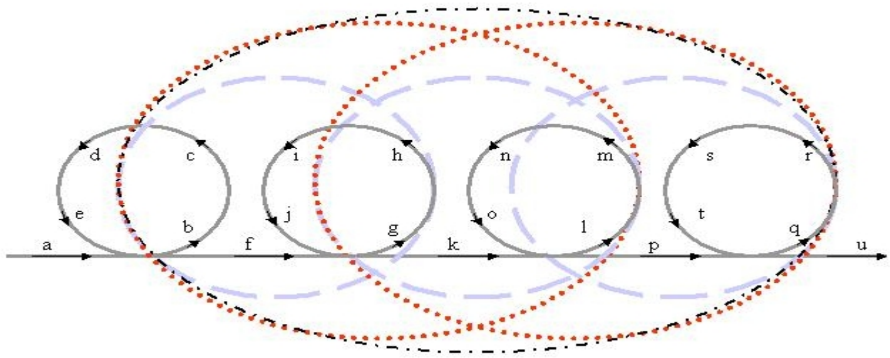

Fig. 6(p). Illustrates multidimensional flexibility of the concept to enable eliciting of maximum understanding from original material - indicated by multiplicity of theoretically available recursive channels (various dotted line ovals radiating from observation phases). This model informs and supports decisions on design and refinement.

3.5 Informed Design and Refinement

Participant action relative to system feedback is a common unit of analysis in SoundScapes. A session facilitator conducts both 'in-action' and 'on-action' assessment - the latter usually with the participant's therapist. Assessment is informed by e.g., facial expressions, non-verbal body language, and utterances. Additional assessment is available though involving 'significant others', e.g., healthcare professional, teacher, therapist or family/friend. As these people know the participants outside of a test situation i.e. Activities of Daily Living (ADLs), their insights assist in assessments, which leads to evaluations that inform the system design refinement for next sessions with each specific participant.

Design and refinement includes making decisions on what is included as available for a facilitator to change in-action. System change parameters affect dynamic relationships as well as system whole and parts. Too many change parameters can lead to redundancy while insufficient reduces flexibility and potential for participant development that may arise. An example of this is when numerous banks of auditory sound patches are used as feedback content making selection overly arduous and operation inefficient.

This chapter informs of an original concept and the motion-sensitive interactive system created as an open research vehicle. Research investigated a supplementary tool for therapists to motivate and enhance disabled users' participation in training. Empowering disabled people to control (physical or digital) artifacts was envisioned to motivate training of whatever body processes were involved in that control thereby offering a non-traditional tool to augment control of that competence. Afferent-efferent neural loop closure and reafferentation training are presented. Apparatus and method have developed along parallel lines through explorative enquiry.

As an open-ended system that is configurable across sensing, mapping, and stimuli, system parameter change variables enable mixing and matching to an individual's profile or therapist goal. Novel non-invasive sensor-based prototypes were created specific for the research and original algorithms were made to facilitate optimal mapping to multimedia content that include audiovisual and robotic device as stimuli.

Overall, response to the work has been positive and related work corroborate potentials through report of participant increased joint-activities, augmented social interaction, and acquiring progressive capacities including 'self-recognized achievement' and 'enhanced sense of control' [e.g., 34, p. 33]. However, system operation/change is problematic for staff, especially when configured beyond a basic system. Reports from use of the 'SoundScapes Room' commissioned in 1999 with staff training and evaluation of use included are of continued use. However, even this basic system a decade later is problematic. If they are not familiar with technology and do not get allocated time to learn it will remain problematic. Thus the models presented in this chapter point to how decisions are made and tentatively suggest how machine supported intervention can assist staff in operation and optimization of practices.

Having a manifold role as inventor/designer/facilitator/researcher included reconfiguring system parameters in the sessions with a significant other (caregiver, therapist, family member, and/or teacher) in attendance. However, training significant others to operate has been problematic as many caregivers proved to be technophobic, unfamiliar or simply not interested in technology – despite the observed positive outcomes. Technical apparatus setup – system apparatus and multiple camera analysis (MCA) system [11], operation and reconfiguration (especially in-action); and the systematic archiving of data for post-session annotation and evaluation were all found problematic for staff who generally were untrained in use of such technology. The emergent model for intervention and evaluation is offered as a first step towards supporting new training that is envisaged required in the field to support optimal use of such technical tools. Therapist training and applied collaborations with digital artist/programmers are foreseen as a direction for next generation practitioners.

3.6 Commercial Products

Commercially available and affordable sensor-based game controllers have recently been adopted into physical training and rehabilitation. Around 2003 the Sony EyeToy was introduced as a single motion-sensing technology device (optical) that enabled control of video game artifacts.

A limited number of studies explored using this device but a common restriction was inaccessible motion data and game content e.g. [9, 43]. Subsequently, Nintendo introduced the Wii platform and game controllers, especially the "Wiimote" and "WiiFit balance board". These are increasingly being adopted in rehabilitation training [24, 29] and education where motivation is reported [4].

Importantly, the controllers allow access to motion data making it available for mapping to control independent content and to archive for analysis to support decision-making. This data stream is also then available to also input to machine-learning of interaction.

3.7 Corroborated Outcomes

Ellis (1995-2004) presents observations of participation progression included from involuntary to voluntary, from accidental to intended, from indifference to interest, from confined to expressive, from random to purposeful, from gross to fine, from exploratory to preconceived, from isolated to integrated, from solitary to individual Whilst terminologies are entities that remain open for subjective interpretation I suggest close corroboration between our findings. The findings point to commonalities of user-experiences, responses, and participant progression that are not limited to specific feedback content or specific input device profile. Simple 'fun doings' experienced as 'magic' emerging from a designed situation matched to a personal profile would seem a key aspect. Important is that the technology needs to be indiscernible and capable of enabling a transparent experience of control of directly and immediately responsive pleasurable content. This then acts as the interface to achieve the desired experience. Decision-making of how to design, refine, and - in sessions - fine-tune the user experience opportunities are key to the work and emanate from facilitator experiences. Machine-supported decision-making to support related investigation and practices is a challenge that lays ahead as such support will assist the burden predicted of future societal demographic dynamics.

In traditional rehabilitation training intervention is focused upon targeting specific impaired skills believed as being the root of dysfunction. Facilitator-led sessions conducted under an *interventionist-centered approach* target achievement of discrete goals and outcomes without consideration of the idiosyncratic preferences, desires, likes and dislikes of the user e.g. [51]. In the author's research, a *whole person approach* is implemented so that the facilitator is responsive to user needs and desires where decisions of system-change targets user-experiences of interaction in activities that are meaningful, interesting and pleasurable. These needs can be user-communicated in-action or resultant from on-action analysis. Under this premise individuals are more likely to be curious, engaged, and activated to participate through articulating via their residual abilities/assets [19]. Thus, design is of situations, interactions and interventions that can support optimizing user motivated participation toward making sense of cause (human feedforward input and subsequent reaction) and effect (content feedback response). Optimized user motivation thus relates to system design where activity challenge is balanced to user skill level, which subsequently relates to aesthetic resonance. Exhibited aesthetic resonance represents achieving closure of the afferent-efferent neural feedback loop towards developing existing assets or acquiring new skills. In this way opportunities to augment a users' understanding about own abilities where their sense of mastery is improved become apparent [41]. Motivated participation can also be a result of user enjoyment from appealing qualities of the created situation or context that attract user interest and curiosity to attract involvement [45]. A created VIS environment stimulates immediate responses to gestures that are designed to please to such an extent that participants become unaware of the effort involved in the generation of movement. Motivation to move resulting from pleasurable and meaningful experiences stimulates motor activities that can have communicational value via associated gestures and expressed representations that often go unnoticed yet in this research they are subject of recursive reflection of exhibited aesthetic resonance. This chapter questions what may be needed in order for a machine to analyze the created situation to support the facilitator and team in making automatic decisions of system-change to assist. The challenge lies in the ability of the machine to interpret innate complexities of subjective evaluation of human behavior and to act upon these interpretations so as to learn idiosyncratic characteristics of the user to effect decisions of system-change.

4 Machine-Supported Intervention

Virtual Reality suggests benefits of use including that it is safe and does not tire or get bored with repetitive mundane activities that may otherwise influence motivation of both user and facilitator [20, 42, 43, 46, and 59]. Contemporary interactive virtual environments are increasingly used in healthcare and rehabilitation. For example, video games[2] are more prevalent in the field following their recent use of untraditional input devices that escape confines of mouse, joystick, and keyboard. Unlike earlier examples, contemporary video games have instructions embedded into the game start (as opposed to manuals that should be read) that enable players to quickly understand input device cause and effect. Often a dedicated opening sequence takes the player through calibration and control of the input device followed by the gameplay situation via examples and demos that are often followed by an initial training challenge. Gameplay then progresses such that as a user achieves a level a subsequent level is presented that offers increased challenges so that skill is augmented. However, many games are limited in their flexibility to address individual users, especially those with special needs/disability. Input devices are programmed to specific interactions with specific content and incremental level challenge may not reflect nuance of skill progression which relates to microdevelopment [62]. Software such as GlovePIE (PC & Linux)[3] or OSCulator (Mac)[4] can improve the situation by enabling parameter mapping of an input device such as the commonly used Wiimote. However, the interaction is still limited to mapping options that can be accessed for content control and such mappings have to be meaningful for the session/program therapeutic goals. Such ‘hacking’ is often beyond the competences and desires of healthcare professionals and weaknesses in robustness of such ad-hoc setups tends to also limit the appeal for practitioners to explore such solutions that could address flexibility to individual needs. The open system that has been used as the core in the author’s research utilizes three robust technologies to capture gesture in an unencumbered untraditional way. Camera, Ultrasound and Infrared technologies are used to designate invisible active zones to source human motion data from gesture. Each has a distinct profile of capture that can be programmed to each individual’s need. The profiles are planar, linear and volumetric and each technique of use offers plusses and minuses in use as an input device to control multimedia content. Applied in the field of rehabilitation non-intuitive technologies have been found to motivate participation

[2] e.g., http://www.usatoday.com/tech/science/2008-02-08-wii-rehabilitation_N.htm
[3] http://carl.kenner.googlepages.com/glovepie
[4] http://www.osculator.net

as they can be programmed to address weaknesses in dexterity and usability is efficient and effective as no additional strength is required to hold or operate an interface. Early investigations prior to contemporary computer vision advances focused on ultrasound and infrared. Both technologies enabled non-computer application so that a facilitator could change system parameters quickly with minimum distraction to the user so as to maintain continuity of contact. Unfortunately it must be said that following extensive observations of use many practitioners are not conversant enough with such interactive systems to be able to evoke fullest potentials for their use which could improve benefits to end-users. Potentials of imitation as a strategy for healthcare and rehabilitation training through interactive virtual reality environments as outlined in this chapter are complex. Relating to the animal kingdom [13] reported how imitation can result in an increase in the frequency of an already acquired motor pattern; can change response orientation in space ('response facilitation'), or even modify the motor pattern of an already acquired action ('action-level imitation'). Whiten [60] reports on how sequential relations between actions can be changed by imitation ('sequence imitation').

Advances in computer vision enable machine recognition of facial expressions and other telling non-verbal bodily reactions to such causal interactions, for example pupil reaction to stimuli, mouth shape, etc. Data streams from user input can be archived to cross-reference to such reactions. Content that affects the user in specific ways can also be synchronized and associated to input data and user reaction. One can imagine how advances in Computer Artificial Intelligence could use such cumulated data and with multi-disciplinary input develop an autonomous support system for assisting in therapeutic situations as outlined in this chapter. A reference intelligent machine systems model with adaptive behavior for real time control change has been proposed[5]. The challenge in this context would seem to be in successfully interpreting all of the data to evoke system parameter change which at the moment is a highly subjective operation due to the complexities of the user interaction and intrinsic and extrinsic variables that can influence session intervention. Such a system, if successful, could enable many more 'next generation' therapists and healthcare givers to introduce interactive technology/multimedia systems into their practice without worry of being alienated of the technology. Strengths & weaknesses exist when making decisions of system devices, protocols and mappings. It is often too much to ask families, carers or even therapists to have needed competences to optimize use of such technology in training and learning. Thus, a specialist training studio is established in Denmark to assist families and to train the trainers. In-session decisions of change that are involved can at the moment only rely on the person leading the session. This can also be the user. Mistakes of parameter-change become evident through experience with the system under this approach to intervention. Automated system decision-making would augment the potentials for such situations. Such progress in the field would support families and self-driven home-training applications. In healthcare, participant activity and motivation are becoming increasingly important as is indicated by the levels of obesity, injuries and disease. In education new

[5] http://www.isd.mel.nist.gov/documents/albus/engineeringmind-96.pdf

paradigms are in place that utilizes the power of interactive digital multimedia into curricula, many involve human performance activities. In both cases, healthcare and education, a tool to supplement by supporting decision-making in an automatic way is seen as advancing state-of-the-art.

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